CHAPTER I
INTRODUCTION

1. INTRODUCTION

Physical training is the basic requirement for sportsmen to achieve a desirable performance. The system of physical training differs in terms of level of competition, nature of sport and gender. The existing system of training in India concentrates more on individualized motor fitness components irrespective of the factors mentioned above though their physical aspects differ. As this type of individualized training prevails in the present scenario none of the sportsmen at different levels will get benefited. Hence, the sportsmen who have acquired basic fitness components in their previous training may achieve high level when they switch over from the system of training that is designed from individualized to complex in nature. This is very essential. Since, complex training is an effective form of physical training that combines both resistance strength training and plyometric explosive power training; it results in deriving the motor fitness component ‘power’.

Power is a product of speed and strength. In any type of sport the fundamental and advanced skills are tailored with this motor fitness component. In order to acquire this valuable motor fitness component, the system of physical training should be designed using the complex training module that is resistance training with plyometric exercises during physical conditioning. For any training program, resistance training is now accepted as integral and crucial part of it. Hence, a conditioning program requires both plyometric training and resistance training to improve some motor fitness components.

At times it appears that concurrent resistance and plyometric training can actually improve power to a greater extent than either one alone. In the recent past, it has been accorded by a few studies that a conditioning program consists of both plyometric and resistance training so as to improve power and its ingredients strength,
speed and flexibility. Among these few studies, some researchers have done the experiments on the effect of complex training by using either resistance training followed by plyometric training or plyometric training followed by resistance training.

The present research is undertaken to recommend a proven method to improve the motor fitness components based on a meticulously scheduled training program by applying Resistance Training followed by Plyometric Training (RPTG) and Plyometric Training followed by Resistance Training (PTRG). Thus it is a unique study making an attempt to find out the philosophy behind how and why Plyometric works after resistance training and before resistance training. In other words it is to find out how the motor fitness components are improved while performing Plyometric Training followed by Resistance Training and resistance training followed by plyometric training.

1.1. TRAINING

Training is a programme of exercises designed to improve the skills and increase the energy capacities of an athlete for a particular event (Edward 1984). The term ‘Training’ is widely used in sports. Some experts especially belonging to sports medicine understand sports training as basically doing physical exercise. Training is the total process of preparation of a sportsman, through different means and forms for better performance.

1.2. SPORTS TRAINING

The very purpose of the training program is aid in the development of acceptable levels of health – and health related physical fitness and promote the acquisition of basic movement skills. To achieve these things, training should have some basic principles. Of these the most basic principle of training is overload. Most physiological systems can adapt to functional demands that exceed these encountered in normal daily life. Training often systematically exposes selected physiologic systems to intensities of work or function that exceed those to which the system is
already adapted. To avoid excessive overload because physiologic systems cannot adapt to stresses to extreme consistency refers to most physiologic systems require exposure to overloading activities three times a week or more. The required frequency of training however depends on the season, the athlete, activity and the specific component of fitness. There is no substitute for consistency in a training program.

The athlete might participate in endurance training six times a week and resistance training three times a week. Specificity means the effects of training are highly specific to the participation physiologic system overloaded, to the particular muscle groups used, and to the particular muscle fibers performing the work progression is the successful training program plan for a steady rate of progression over a long period. The athlete has to improve over several years of participation; the training program must progress so that the appropriate physiological systems continue to be overloaded. However, too rapid an increase of the training stress may lead to exhaustion and impaired performance. Individuality means factors such as age, sex, maturity, current fitness level, years of training, body size, somato type and psychological characteristics should be considered by the coach in designing each athlete’s training regimen. In large groups in which absolute individualization of training programs may be impractical, the coach should strive for individualization by homogeneously grouping athletes.

1.3. AIMS OF SPORTS TRAINING

The major aim of sports training is to achieve high level performance. The sports performance depends largely on physical fitness and motor fitness. The physical fitness can be differentiated into general and specific fitness. Each sports activity demands different types and level of different motor abilities and when a sportsman possesses these, he is said to have the specific physical fitness of various motor abilities, regardless of any sports which the sportsman possesses. The contribution of physical fitness towards sports performance is indirect. But it should never be overlooked that specific physical fitness depends largely on the general physical fitness (Hardayal Singh, 1983).
1.4. PRINCIPLES OF TRAINING

Training to improve an athlete's performance obeys the principles of training: specificity, overload, recovery, adaptation and reversibility.

1.4.1. SPECIFICITY

Specificity of training states that sports training should be relevant and appropriate to the sport for which the individual is training in order to produce a training effect.

To improve the range of movement for a particular joint action, the athlete to perform exercises that involve that joint action. It is quite possible for an athlete to have good mobility in the shoulder joint but to have poor hip mobility. Conducting shoulder mobility exercises may further improve the shoulder mobility but it will not affect hip mobility.

In addition to developing general levels of all round mobility in an athlete, coaches need to consider the specific mobility requirements of a given event. The coach can analyze the technique of his event, identify which joint actions are involved and determine which need to be improved in terms of the range of movement.

The amount and nature of the mobility training required by each athlete will vary according to the individual athlete's event requirements and individual range of movement for each joint action. It may be necessary to measure the range of movement for particular joint actions to determine the present range and future improvement.

Specificity is an important principle in strength training, where the exercise must be specific to the type of strength required, and is therefore related to the particular demands of the event. The coach should have knowledge of the predominant types of muscular activity associated with his/her particular event, the movement pattern involved and the type of strength required. Although specificity is important, it is necessary in every schedule to include exercises of a general nature (e.g. power clean, squat). These exercises may not relate too closely to the movement
of any athletic event but they do give a balanced development and provide a strong base upon which highly specific exercise can be built. Training at low velocity increases low velocity strength substantially but has little effect on high velocity strength (Coyle and Fleming, 1980).

Slow velocity training may be of value in stimulating maximum adaptation within the muscle. Muscle growth (and increase in contractile strength) is related to the amount of tension developed within the muscle (Goldberg, 1975). When an athlete performs high velocity strength work, the force he/she generates is relatively low and therefore fails to stimulate substantial muscular growth. If performed extensively the athlete may not be inducing maximum adaptation with the muscles. It is important therefore for the athlete to use fast and slow movements to train the muscles.

1.4.2. OVERLOAD

A strength training principle which states that the intensity of exercise must be high enough above normal for physiological adaptation to occur. In other words, if you want to see results when lifting weights, you have to lift more than your muscles can handle. That overload will cause the muscle fibers to grow stronger and, sometimes, bigger in order to handle the extra load.

When an athlete performs a mobility exercise, he should stretch to the end of his range of movement. In active mobility, the end of the range of movement is known as the active end position. Improvements in mobility can only be achieved by working at or beyond the active end position. Passive exercises involve passing the active end position, as the external force is able to move the limbs further than the active contracting of the agonist muscles. Kinetic mobility (dynamic) exercises use the momentum of the movement to bounce past the active end position.

A muscle will only strengthen when forced to operate beyond its customary intensity. The load must be progressively increased in order to further adaptive responses as training develops, and the training stimulus is gradually raised. Overload
can be progressed by increasing the resistance, increasing the number of repetitions with a particular weight, increasing the number of sets of the exercise (work) and increasing the intensity- more work in the same time i.e. reducing the recovery periods.

1.4.3. RECOVERY

The physiological processes that restore the body to its pre-exercise condition after exercise. Recovery includes replenishment of muscle glycogen and phosphagen (the energy stores in the muscles); removal of lactic acid and other metabolites (the waste products of muscle activity); reoxygenation of myoglobin (the special respiratory pigment which provides muscles with an extra source of oxygen); and replacement of protein (needed to repair muscles damaged during exercise).

Recovery can be accelerated by ensuring body fluids lost in sweat are replaced with water; by replacing mineral salts lost in sweat (especially sodium and potassium); and by eating enough nutrients (especially foods that can be converted to muscle glycogen) to replace those lost during the exercise.

Rest is required in order for the body to recover from the training and to allow adaptation to take place.

1.4.4. ADAPTATION

Adaptation is the way the body 'programs' muscles to remember particular activities, movements or skills. By repeating that skill or activity, the body adapts to the stress and the skill becomes easier to perform. The Principle of Adaptation explains why a beginning exercisers are often sore after starting a new routine, but after doing the same exercise for weeks and months the athlete has little, if any, muscle soreness. This also explains the need to vary the routine and continue to apply the Overload Principle if continued improvement is desired. The body will react to the training loads imposed by increasing its ability to cope with those loads. Adaptation occurs during the recovery period after the training session is completed. If exercises lasting less than 10 seconds (ATP-CP energy system) are repeated with a full
recovery (approximately 3 to 5 minutes) then an adaptation in which stores of ATP and CP in the muscles are increased. This means more energy is available more rapidly and increases the maximum peak power output. If overloads are experienced for periods of up to 60 seconds, with a full recovery, it is found that glycogen stores are enhanced.

The most noticeable effect of weight training with heavy loads on fast twitch muscle fibers is larger and stronger muscles (hypertrophy).

The rate of adaptation will depend on the volume, intensity and frequency of the exercise sessions. In their recent investigation Burgomaster et al. (2008) reports that 6 weeks of low-volume, high-intensity sprint training induced similar changes in selected whole-body and skeletal muscle adaptations as traditional high-volume, low-intensity endurance workouts undertaken for the same intervention period.

Hawley (2008) states that the time of adaptation may be quicker for high-intensity sprint training when compared to low-intensity endurance training, but that over a longer period, the two training regimens elicit similar adaptations.

1.4.5. TEDIUM

When planning a training programme, it is important to vary the training a bit to prevent performers becoming bored. If every training session is the same, a performer can lose enthusiasm and motivation for training. Hence, it should include a variety of different training methods or vary the type of activity.

1.4.6. PROGRESSION

Progression means gradually increasing the amount of exercise. When a performer first starts exercising, their levels of fitness may be poor. If a coach increases the training too quickly, the body will not have time to adapt and this may result in injury. Slow and steady progress is the best way forward.

Gradually increasing the frequency, intensity and duration of fitness sessions is an important factor in developing an effective training programme. In terms of type of training, progression should be based on the principle of moving from easy activities to difficult ones.
1.4.7. MODERATION

Moderation means achieving a balance between not training enough and overtraining. Achieving the right balance is very important. Without proper rest and recovery time, performers can become too tired to train effectively and become stressed and irritable.

Even worse, overtraining can lead to injury. This can occur through overstressing joints and tissues, or through poor technique resulting from exhaustion.

1.4.8. REVERSIBILITY OR DETRAINING

The Reversibility Principle states that athletes lose the effects of training after they stop. During the off season, active participation in other sports or activities minimize transfer" is a concept socio-culturally rather than objectively defined.

Improved ranges of movement can be achieved and maintained by regular use of mobility exercises. If an athlete ceases mobility training, his ranges of movement will decline over time to those maintained by his other physical activities.

When training ceases the training effect will also stop. It gradually reduces at approximately one third of the rate of acquisition (Jenson and Fisher, 1972). Athletes must ensure that they continue strength training throughout the competitive period, although at a much reduced volume, or newly acquired strength will be lost (Godfrey, R. (2005)

1.4.9. INTENSITY

The quantitative, rather than the qualitative aspect of stimulation and experience; for example, the magnitude or amplitude of sound waves as distinguished from their frequency (Hawely, J 2008).

1.4.10. FREQUENCY

Frequency measures the number of occurrences of a repeating event per unit time (Godfrey, R.J 2005).
1.5. TYPES OF TRAINING

In developing the motor fitness components of university sportsmen are being treated with varied forms of training such as resistance training, plyometric training, interval training, harness running that is speed based training and combination of training. Of these, resistance training, plyometric training and combined training used in the present study are explained below.

1.5.1. RESISTANCE TRAINING

It is a form of exercise for the development of strength and size of skeletal muscles. It is a common type of resistance training, which is one form of strength training. When one does it properly it can provide significant functional benefits and improvement in overall health and well-being. In one common training method the teaching involves lifting progressively increasing amount of weight and uses a variety of exercises as type of equipment to target specific muscle group. It is primarily an aerobic activity although some proponents have adopted it to provide the benefits of aerobic exercises.

Resistance training is also known as weight training or strength training. It is an important tool for achieving a complete healthy life. Resistance training is not only for athletes, but also for those who want to build or tone muscle by using resistance training to achieve a better looking body. One may also hear the terms weight training (or weight lifting) and strength training used to describe working the muscles with resistance. Resistance training is the term used to describe using weights, machines, and even one’s own bodyweight to effectively work one’s muscles. It is an umbrella term used to accurately describe all forms of resistance training, whether working with weights or not. Although strength training accurately describes what resistance training does. Many people do not use the term because they think it only applies to those trying to become bigger and stronger when, in fact, all resistance training which is correctly done indeed increases strength, but does not necessary visibly increase size. Resistance training does improve the look and tone of the body but it is now known to be more than just a specialized exercise activity.
Resistance training environment involves numerous types of equipment to improve variety in a health-club of physical capacities - from improving daily movement to enhancing performance or changing appearance. In particular, resistance training improves the functional performance of the neuromuscular system - the system of muscles and nerve pathways that direct and control movement.

Resistance training produces increased strength, superior movement performance and general fitness, including enhanced function of the respiratory, cardiac and metabolic systems. Other improvements include an increase in muscle mass, strengthening of connective tissue and supportive tissue as well as improvements in posture and physique. Resistance training has many psychological benefits as well. It can boost self-confidence, increase motivation, enhance perseverance and produce a strong commitment to fitness. Serious athletes do not need reminding of the importance of integrating resistance training into their year-round conditioning regimes. They know there is no quicker way to significantly boost their levels of strength, speed – and even their endurance.

Strength training using isometric exercises was popularized by Charles Atlas (1930). The 1960s saw the gradual introduction of exercise machines into the still-rare strength training gyms of the time. Weight training became increasingly popular in the 1980s, following the release of the bodybuilding movie Pumping Iron and the subsequent popularity of Arnold Schwarzenegger. Since the late 1990s increasing numbers of women have taken up weight training, influenced by programs like Body of life. The two benefits from traditional strength work are increased neural activity and increased muscle mass (hypertrophy).

To develop the rate of force the Type IIb muscle fibres need to be targeted as these are the ones that produce force most explosively allowing for maximum power. The sorts of exercises that develop the Type IIb fibers are: Speed strength exercises, e.g. weighted squats jumps What athletes do need is reliable, unbiased and up-to-date information on resistance training Best Practice – particularly the central issue of how one increases strength and power without adding unnecessary bulk, a subject on which it is rare to find independent, evidence-based advice.
Hippocrates wrote, “That which is used develops and that which is not used wastes away” A repetition is the act of lifting and lowering a weight once in a controlled manner; a set is lowest of several repetition performed one after another with no break between them. Weight training creates muscle growth by causing microtrauma to the muscles. Weight also provides functional benefits.

Stronger muscles improve posture and provide better support for joints. Stronger muscles improve performance in a variety of sports. During the past few years, endurance athletes in a number of sports have added resistance exercises to their training programs to boost their muscle power. Scientific studies have linked resistance training with a reduced rate of injury in athletes. It fortifies leg muscles and strengthens ‘weak links' in athletes' bodies, including the often-injured hamstrings and shin muscles, as well as abdominal and low-back muscles. Resistance work also improves tendon and ligament strength and increases bone density, which decreases the risk of injury.

It is common knowledge that all other things being equal, a weight trained muscle is not only better able to generate force; it is also more resilient and less susceptible to injury. But while the effects of different weight training regimes on muscular performance are well understood, few athletes or coaches are aware of the effect of weight training on hormone balance in the body. As John Shepherd explains, these weight training induced hormonal changes have a profound effect on musculature, body weight and subsequent performance of an athlete.

1.5.2. BENEFITS OF RESISTANCE TRAINING

As the goal of resistance training, the (ASMI) American sports medicine institution says, is to “gradually and progressively overload the musculoskeletal system so it gets stronger”. Regular resistance training will strengthen the bones, and it build well on strengthen the muscles. Strength training offers a way of balancing that out by challenging all the major muscle groups, including those in the chest, arms, back and abdomen. According to medical research, generally the resistance training strengthens the muscular system, strengthens the skeletal system, and
improves bone density (decreases the chance of osteoporosis) and increases metabolism. So a well-planned resistance training program should be a part of everyone’s health, fitness and lifestyle regardless of age, gender or goals.

In particular, resistance training improves the functional performance of the neuromuscular system - the system of muscles and nerve pathways that directs and controls movement.

Resistance training produces increased strength, superior movement performance and general fitness, including enhanced function of the respiratory, cardiac and metabolic systems. Other improvements include an increase in muscle mass, strengthening of connective tissue and supportive tissue as well as improvements in posture and physique.

1.5.3. PLYOMETRICS

Plyometrics by definition is, a type of exercise using explosive movements to develop muscular power, especially, bounding, hopping and jumping. This is a somewhat narrow interpretation. Plyometrics or ‘Shock method training’ is the term now applied to exercises that have their roots in Russia, where it was first known simply as jump training drills. The actual term “Plyometrics” was first coined in Fred Wilt (1975) one of America is more forward-thinking track and field coaches. Based in Latin origins ploy + metrics means “measurable increases”.

Plyometric is a term that describes exercises that help bridge the gap between strength and speed. It refers to human movement that involves an eccentric muscle contraction immediately and rapidly followed by concentric contraction. The main objective in plyometric training is to improve quickness through strength. The fast twitch or white fiber is responsible for explosive type of muscular contraction. Dr. Chu (1996) states “Plyometric has undergone a considerable metamorphosis over the past few years. New ideas and techniques will lead the reader into the second generation of plyometric training. The coach or trainer who understands the options and opportunities available through plyometric will find new ways to train athletes”.

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“Throughout the 1980’s coaches in sports such as volleyball, football and weight lifting began to use plyometric exercises and drills to enhance their training programme. If there was any draw back to this enthusiasm it lay with the lack of expertise that American coaches and athlete had in administrating plyometrics and the faulty belief that more must be better”, as commented by Chu (1996).

Plyometrics can best be described as a reflexive form of power training. This type of training involves powerful muscular contractions in response to a rapid stretching of the involved musculature. These powerful contractions are not a pure muscular event. In fact they primarily involve and augment the nervous system. It is the combination of involuntary reflex (Myotatic “stretch-reflex”) which is then followed by a fast muscular contraction. This is the basic idea behind the question of the ability of plyometric training to improve athletic performance, particularly sprints and jumps, which continues to be debated. Many researchers have searched, and continue to search, to answer whether plyometrics can be the link between strength training and power development. Based on scientific discoveries, it is our position that, with proper preparation, instruction, and progressions, plyometric training can be an effective method of training athletes explosively while also preventing injury.

In Yuri Verkhoshanski (1966), a Soviet jumping coach, discussed the importance of finding new methods to improve athletic performances because traditional training protocols, which included high volumes of jump training plus weight training, were becoming less effective. Verkhoshanski observed that the athletes, who spent the least amount of time on the ground, or in the amortization phase, displayed the greatest jumping performances. Based on this observation, he reasoned that the athletes’ muscles must also be strong eccentrically in order to withstand the high mechanical forces placed on the body during the amortization phase. Training the muscles eccentrically, he believed, would enable them to overcome the eccentric loading quickly to concentrically contract immediately, propelling the body in the desired direction. This allows the athlete to exploit the energy stored in the muscle during the eccentric stretch phase. Therefore, by
increasing the amount of tension the athlete can generate during the eccentric contraction and by improving the reactive ability of the muscles in switching from eccentric to concentric work, improvements in jump performance can be made (Verkhoshanski 1966). Verkhoshanski realized early on, however, that in order for improvements to be made, proper progressions must exist.

Fred Wilt (1975) wrote of plyometrics as a training technique used by European coaches as a means to bridge the gap between sheer strength and speed. Wilt even suggested that Valery Borzov’s surprising wins in the 100 and 200 meter sprints at the 1972 Olympics were due in large part to his plyometric training. This article led to the widespread implementation of plyometrics into American training, but also sparked the ongoing debate on the effectiveness of plyometric training for improving athletic performances. This type of training was made famous by Eastern European athletes, who were continually beating North American athletes at most strength and speed events. Through the late 70's and 80's plyometrics became an integral part of any sports conditioning program.

This literature review has attempted to offer a comprehensive look at the history, development, and effectiveness of plyometric exercises. It has also attempted to provide a clear understanding of how to safely implement a successful plyometric training program. Although originally developed by (NASA) The National Aeronautics and Space Administration and then by the Soviets for sport, plyometrics has become a mainstream training method for athletes. Numerous studies have shown both the effectiveness in producing athletic improvements and also as a rehabilitative device, especially when combined with strength training. Many misconceptions and critics of plyometrics still exist, however Critics suggest that plyometrics are a dangerous training method and cause injury. But no studies confirm these beliefs when plyometrics are taught and progressed properly. Progressions are an essential part of any plyometric routine to minimize the risk of injury to an athlete. Athletes must progress through the exercises individually, constantly monitoring posture, balance, stability, and flexibility. When these reach satisfactory levels, only then will
the athlete progress to more complex, higher intensity drills. When taught and progressed properly, plyometrics can be an extremely effective method of developing athletic power, increasing maximal strength, and preventing injury. Wherever one looks in the world of top-class sport, power counts one of the best ways of developing this most precious commodity is through plyometric training.

Plyometric exercises are based on the understanding that a concentric (shortening) muscular contraction is much stronger and it immediately follows an eccentric (lengthening) contraction of the same muscle. It is a bit like stretching out a coiled spring to its fullest extent and then letting it go: immense levels of energy are released in a split second as the spring recoils. Plyometric exercises develop this recoil or, more technically, the stretch/reflex capacity in a muscle. With regular exposure to this training stimulus, muscle fiber should be able to store more elastic energy and transfer more quickly and powerfully from the eccentric to the concentric phase. However, to get the best out of plyometrics one needs adequate preconditioning. And that is where weight training can play a crucial role. Moreover, when it comes to selecting the right plyometric moves, the coach or athlete needs to consider the specifics of their sport, the athlete's maturity, his level of pre-conditioning and his ability to pick up what can be a complex skill.

Plyometric training is now a common element of elite sports training programs, and is increasingly used by other athletes and their coaches. But while its beneficial effects on the lower body are well documented, there are some lingering doubts over how useful it is for upper body force development.

First documented as an effective training method by Soviet coaches in the middle of the last century, the main purpose of ‘plyometrics’ is to increase the rate of force development, the key ingredient of power. By contrast, the main purpose of heavy weight training is to increase total force production – i.e. maximum strength.

It is logical for athletes to seek to increase the rate of force development, because most sporting movements involve fast movements, for which forces must be generated quickly. The foot-to-ground contact time in high jump, for example, is less
than 100 milliseconds, yet it will take around 500 milliseconds to generate maximum force. For elite performance, an athlete’s rate of force development is often more important than the maximum force he or she is able to generate.

The other advantage of plyometric training is that it comprises jumping and throwing movement patterns that involve a stretch-shortening-cycle (SSC). The muscle and tendons are first lengthened with an eccentric load – e.g. pulling back your arm to throw a ball – which may increase the subsequent concentric force production and/or allow release of elastic energy – e.g. as the arm accelerates forwards to release the ball. Since most sporting movements involve sprinting, jumping and throwing SSC movements, plyometric training can be viewed as highly sport specific plyometrics, which if not used wastes away." Progressive resistance training dates back at least to, ancient Greece when legend has it that the wrestler Milo of Corton trained by carrying a newborn calf on his back every day until it was fully grown. Another Greek, the physician Galen, described strength training exercises using the halters (an early form of dumbbell) in the 2 century.

A requirement for using Plyometrics in one’s training programs is an understanding of what Plyometrics is and how it works. Dr. Chu's commentary, embedded the science of Plyometrics with, advances in thinking regarding their use in sports specific training programs. For example, he states "Throughout the 1980's, coaches in sports such as volleyball, football, and weightlifting began to use Plyometric exercises and drills to enhance their training programs. If there was any drawback to this enthusiasm, it lay with the lack of expertise that American coaches and athletes had in administering Plyometrics and the faulty belief that more must be better".

Simply stated and starkly accurate, plyometrics defined as "exercises which enable a muscle to reach maximum strength in as short a time as possible". This speed-strength ability is known as power.
1.5.4. COMBINED TRAINING

For many years coaches and athletes have sought to improve power in order to enhance performance. Throughout this century and no doubt long before, jumping, bounding and hopping exercises were especially used in various ways to enhance athletic performance. In recent years this distinct method of training for power or explosiveness has been termed Polymerics. Plyometrics by definition is, a type of exercise using explosive movements to develop muscular power, especially bounding, hopping and jumping. It is a term that describes exercises that help to bridge the gap between strength and speed, and refers to human movement that involves an eccentric muscle contraction immediately and rapidly followed by concentric contraction. When a muscle is lengthened, energy is released as heat, but some energy is stored in the muscles and tendons to be used in its subsequent contraction. The goal is to decrease the amount of time it takes for the muscle to contract in a movement. Again the focus is on time. If the muscle is stretched for too long, useable energy is lost as heat.

Plyometric training, termed as “explosive-reactive” is a power training, that involves powerful muscular contractions in response to a rapid stretching of the involved musculature. These powerful contractions are not a pure muscular event; they have an extremely high degree of central nervous system involvement. The event is a neuromuscular event. It is a combination of an involuntary reflex (i.e. a neural event), which is then followed by a fast muscular contraction (i.e. voluntary muscular event). The main objective in plyometric training is to improve quickness through strength. The fast twist or white fibre is responsible for explosive type of muscular contraction. Chu (1996) states “Plyometric has undergone a considerable metamorphosis over the past few years. New ideas and techniques will lead the reader into the second generation of plyometric training.

1.5.5. UPPER BODY PLYOMETRICS

Upper body plyometrics is believed that the stretch-shortening cycle (SSC) can be activated in the upper body just as it is in the lower body. The most common
method of upper body plyometrics is with a medicine ball Wilk (1993). Chu (1989) described many different medicine ball activities which allow the athlete to strengthen in ways unavailable through use of free weights. These exercises are used to develop power from sheer strength. Chu (1996) illustrated the use of upper body plyometrics as a means of training functional power through his use of medicine ball chest passes. Football players who were much stronger in the weight room, were clearly outperformed by javelin throwers who were much more accustomed to performing this powerful movement. Radcliffe and Farentinos (1999), Armstrong (1994) and many others have since developed upper body plyometric training protocols.

1.5.6. LOWER BODY PLYOMETRICS

Lower body plyometrics is believed that the stretch-shortening cycle can be activated in the lower body. The most common method of lower body plyometrics is that it involves box jump, hopping, bounding, depth jump, jump and reach, jump and tug, lateral over the cones, jump using cones and hurdles. It helps develop power in any sport that involves sprinting, jumping, quick changes of direction and kicking, etc. These are most effective when completed in conjunction with a suitable strength training program or following a phase of maximal strength training.

1.5.7. COMPLEX TRAINING

It is a highly effective form of physical training that combines both resistance strength training and plyometric explosive power training. The idea is to use the combination of resistance and plyometric exercises to superbly engage the nervous system and activate more fibres. Complex training describes a power-developing workout that combines weights and plyometric exercises. About 10 years ago, these workouts were greeted with great acclaim as research indicated that they could significantly enhance fast twitch muscle fiber power and, therefore, dynamic sports performance.

According to Beachle & Earle (1994) complex training is a combination of high intensity resistance training followed by plyometrics. Ebban (2002) states that
complex training alternates bio-mechanically similar high load weight training exercises with plyometric exercises.

1.6. COMPLEX TRAINING THEORY

The proposal of the theory underpinning complex training is for training the neuromuscular system specifically for maximum power output and force development and for maximizing the involvement to the fastest muscle fibres. According to Ebban and Watts (1998) “High load of weight increases motor neuron excitability and reflex potentiation, which may create optimum entry conditions for subsequent plyometric exercises. Also the fatigue associated with high load weight may force more motor units to be recruited during the plyometric phase for the possible enhancing of the training state.

According to Hakkinen et al. (1998) the strength training in combination with some explosive types of exercises be recommended as a part of overall physical training to maintain the functional capacity in middle-aged and elderly people. For explosive muscle performance, the underlying factors are muscle fibre type, muscle hypertrophy and enzymatic and neural adaptations. It is also important to investigate the impact of power-type strength training on the low back and leg muscles and joints, as well as the injury risks and adherence, and motivation to training. For being effective in improving the explosive muscle performance, training programs should be designed so as to be motivating, easy to achieve, effective concerning the time spent in exercises, low in expenses, and they should give consideration to the exercise history and present exercise activity, health status and musculoskeletal symptoms and diseases of the individual.

Combining both resistance strength training and plyometric explosive power training is to use the combination of resistance and plyometric exercises to superbly engage the nervous system and activate more fibres Beachle & Earle (1994). Ebban (2002) states that resistance training followed by plyometric training alternates bio mechanically similar to high load weight training exercises with plyometric exercises. This type of training describes a power-developing workout that
combines weights and plyometric exercises. The logic behind this pair of exercise is that the resistance work gets the nervous system into full action so that type II b fibres are available for the explosive exercise; hence a better training benefit of complex training programme can be used in the general, specific and competitive phase of training.

Complex training is a workout comprising of a resistance exercise followed by plyometric exercise e.g. squats followed by squat jumps; bench press followed by plyometric press up. The logic behind these matched pair of exercise is that the resistance work gets the nervous system into full action so that more type IIb fibers are available for the explosive exercise, hence a better training benefit of complex training programme can be used in the general, specific and competitive phase of training. Ebbon (2002) in his recent literature review has stated that complex training has investigated both the acute and long term effects of this conditioning approach. Complex training describes a power-developing workout that combines weights and plyometric exercises. The two benefits from traditional strength work are increased neural activity and increased muscle mass (hypertrophy).

Many athletes include plyometric exercises in their training programs and are well aware of their benefits. However it is slightly less known that the combination of traditional strength with power and plyometric exercises together results in greater Type II b recruitment and consequently greater improvements in power and rate of force development. One of the most effective ways to build power is with plyometrics, a form of exercise involving explosive movements, such as jumping over or onto a high box. Including such exercises in a triathlete's routine is quite effective, but the problem is that it takes more time than most of us have available. When one is already swimming, cycling, running and lifting weights, adding one or two more workouts to the week is close to impossible.

The combination of plyometrics and weights into one session is known as "complex training." Not only does training save time, it also magnifies the effect of plyometrics.
This is because lifting weights stimulates the nervous system to activate more muscle fibres for a couple of minutes following an exercise. And recruiting large numbers during plyometric exercise means great power generation. So by combining two in one workout time radically improves power. Quality of training is the key to gaining both strength and power. By combining weights and plyometrics into a single workout and limiting the number of exercises to only multi-joint movements that most closely simulate the movements of volleyball and swimming, one can dramatically improve both strength and power. Complex training is a workout comprising a resistance exercise followed by a matched plyometric exercise e.g. squats followed by squat jumps, bench press followed by plyometric press up. The logic behind these matched pair of exercises is that the resistance work gets the nervous system into full action so that more Type II b fibres are available for the explosive exercise, hence a better training benefit. During complex training one should not learn new exercises or work on technique since complex training is a very intense form of exercise, one must rest properly before, after and during the complex training workout one should rest at least 48 hours between complex training workouts and rest 2-5 minutes, or longer, between exercise pairs.

The strength exercise is performed first followed by the plyometric exercise for improving the training benefit by getting the nervous system and muscle fibers primed to perform the explosive plyometric exercise better.

1.7 MOTOR FITNESS COMPONENTS

1.7.1. Speed

Absolute speed is determined by a number of factors the obvious one being genetics. A good speed training program will improve the efficiency of muscle fibres (if not the type or amount of them) and that will make faster. So, the speed training schedule should be to increase sprinting power - particularly acceleration and speed off the mark.
Speed endurance training significantly improves recovery after a bout of repetitive sprints. Further, speed training program should improve agility, foot speed and reaction time.

Speed in training theory defines the capacity of moving a limb or part of the body’s lever system or the whole body with the greatest possible velocity. Maximum value of such movements would be without loading. Thus, the discus thrower’s arm will have greatest velocity in the throwing phase if no discus is held and velocity would be reduce as the implement’s weight in increased relative to the athlete’s absolute strength.

Speed is measured in meters per seconds, as for example, in quantifying the value for speed of moving one part of the body in sprinting or at point of take to another, the forward speed of the velocity of implements and balls at release or on being struck. The time taken to sprint 30m or again, the number of the repetitions of a task within a short period of time might be considered an index of speed. For example, the number of repetition run in shuttle run over 5m in 20seconds.

Strength in itself will not influence maximum speed of limb movement, but developing greater strength and applying it at speed will certainly positively influence performance. There is a critical sequence in the progression of developing performance in this respect.

Speed is a critical component of that complex requirement for achievement in competitive sport.

‘optimal’ speed is as close to maximum as possible without compromising the technical model(s). In endurance sports, speed’s role on the one hand expands the range of tactical variants. (sports training principles, Frank W. Dick (2002) fourth Edition).

1.7.2 Agility

In general, agility is defined as "the ability of a system to rapidly respond to change by adapting its initial stable configuration."
Agility is the ability to change the body's position efficiently, and requires the integration of isolated movement skills using a combination of balance, coordination, speed, reflexes, strength and endurance. Agility is the ability to change the direction of the body in an efficient and effective manner and to achieve this to require a combination of: balance - the ability to maintain equilibrium when stationary or moving (i.e. not to fall over) through the coordinated actions of our sensory functions (eyes, ears and the proprioceptive organs in our joints); static balance - the ability to retain the centre of mass above the base of support in a stationary position; dynamic balance - the ability to maintain balance with body movement; speed - the ability to move all or part of the body quickly; strength - the ability of a muscle or muscle group to overcome a resistance; and lastly, co-ordination - the ability to control the movement of the body in co-operation with the body's sensory functions (e.g. catching a ball [ball, hand and eye co-ordination]).

In sports, agility is often defined in terms of an individual sport, due to it being an integration of many components each used differently (specific to all of sorts of different sports). It is a common testing variables measured during most athletic performance variables to measure. A variety of different agility test can be selected. However, agility testing provides more relevant information if the test selected incorporates movements that are similar to the movements the athlete performs during competition and if the test is part of the atheletic training program. (Sheppard JM, Young WB 2006).

1.7.3 Flexibility

Flexibility is the ability to move a muscle or a group of muscles through the complete range of motion. All stretching exercises should be preceded by a warm-up. The elevated muscles temperature and increased mobility of connective tissue and joints generated by the warm –up allow for a greater range of motion to be reached during each stretching exercise. Flexibility exercises are generally performed before exercises or competition but may also be performed afterward during the cool-down period. Stretching during the post exercise cool-down period should be performed
within a short time of the conclusion of practice or competition (5-10 min.) to take advantage of the elevated muscle temperatures. Post exercises stretching may also decrease muscle soreness (Prentice 1983). However, there is little experimental evidence to support this contention.

The muscle proprioceptors, golgi tendon organs and muscle spindles, are sensory neural fibres that relay information about the muscle stretch to the upper neural pathways. Their primary responsibility is to protect the muscle from injury. The golgi tendon organs are located in the tendons of the muscle fibres, and the muscle spindles considered intrafusal fibers and are situated parallel to the muscle fibre. Golgi tendon organ are sensitive to tension development in the muscle tendon complex. They inhibit contraction of agonist muscles and activation of antagonist muscles when tension within within the muscle tendon complex is increased to a level that poses a risk of injury to the muscle. The muscle spindles are responsible for monitoring the stretch and length of the muscle and initiating contraction within the muscle to reduce the stretch if need.

As the muscle lengthens during a stretching exercise, the muscle spindles become activated, causing a contraction of the muscle that is being stretched. During a rapid stretch that might be seen in a ballistic or bouncing type movement, both the tension in the tendon organ and muscle spindles activated, causing a rapid contraction of the muscle. This stretch reflex is easily demonstrated by a light tap to the patellar tendon and the consequent contraction of the quadriceps muscle to ease the tension on the muscle spindles and golgi tendon organs. It is for this reason that slow static stretching, which result in a more relaxed and effective stretch, is recommended (Alter 1996).

**Physiological factors of flexibility**

As we age, the elasticity of the muscle is reduced resulting in a decrease in range of motion. Reduced elasticity is caused by increased fibrous cartilage replacing degenerated muscle fibres, increased adhesions and cross-link within the muscle, and increased calcium deposits (Alter 1996). However, flexibility training can still be
beneficial in an older population, as demonstrated by the improved range of motion (ROM) in elderly subjects after 10 weeks of stretching exercises performed 3 days per week (Girouard and Hurley 1995).

Gender also appears to affect muscle and joint flexibility. Females tend to be more flexible than males at all ages. This is primarily attributed to gender difference of pelvic structure and hormonal concentrations that may affect the laxity of connective tissue (Alter 1996).

Physically activity is an important determinant of flexibility because active people tend to be more flexible than sedentary individuals (Kirby et al., 1981, M.C. Cue 1953). Inactivity causes tightening or contraction of inactive muscles this is easily understood considering the stiffness one feels after sitting for a prolong period. During long duration of inactivity as result of deconditioning or immobilisation, the connective tissue of the muscle become shortened, reducing it’s range of motion about a joint.

1.7.4. Strength

Strength is the most important element in motor performance. Strength is a consistent differentiator of ability to make and to achieve success in sports. It is the ability to overcome resistance or to act against resistance. Muscle strength is that which acts when the nervous system communicates a message to the muscle fibers to contract so as to produce force. It is in fact a product of voluntary muscular contractions caused by the neuromuscular system. Strength should be a significant part of training young, elite or recreational athlete. Strength has direct or indirect influence on most of the abilities needed for performance. The abdominal strength is very much useful in the field of sports and games. When an individual possess a high degree of abdominal strength, he will be able to perform any type of activities such as running, jumping and throwing. The abdominal strength helps to maintain the body postures, thereby involving in many activities in the field of sports and games.
Hence the young players develop strength through natural, unbroken movements such as jumps, throws and other body weight exercises. Strength training serves not only to improve overall performance, but also to secure the body and help the players avoid injury. Proper strength training has the potential to increase soccer performance, and that strength training should therefore be an integral part of all sportsmen.

1.7.5. Leg Strength for Sport Performance

The legs are the primary source of power in many sports. In majority of situations they function as part of a closed kinetic chain which means that one leg is always in contact with the ground. Without functional leg strength the athlete can not have speed, strength, power or suppleness to perform. It is to think of the legs as a functional unit of the whole kinetic chain. "Function is a miraculous and complex combination of systems that are linked so that they react with each other. In order to understand function as a whole, the parts and components of function must be appreciated" (Gary Gray, 2001). The leg muscles work together to reduce and produce force in the most effective manner for the required activity.

1.7.6. Power

Power is the product of force, strength and velocity. Power is the ability to exert strength in a given time frame and ability to exert force quickly. A simple equation for power is: muscular strength X speed = Power (Bryant, 1988). Power is considered to be a combination of strength and speed. Power equals four times velocity and has to do with the speed of the contraction against less than maximal resistance. Power is closely related to dynamic strength, with speed or quickness of movement as the added dimension. Although strength, speed and power are related, strength alone will not develop power. Power is displayed in many activities in different ways. Dribbling the ball, shooting the ball, throwing the ball and rebound are the examples for power needed in basketball.
1.7.7. Muscular Power

It is the ability to release maximum force as fast as possible. It is a maximum muscular contraction against a resistance in a minimum amount of time. Power = Force x Velocity. It is a compound element of motor fitness. It needs specific muscular strength, speed of limb movement and skill in integrating and co-coordinating the action. Increased velocity of parts of the body is related to improve neuromuscular initiation, co-ordination and precision of movement patterns.

When a highly skilled level is attained, further performance improvement is primarily attributable to the increase in strength. Muscular power exists in its own right. Strength and power are separate entities.

1.7.8. Explosive Power

Successful sporting performance at elite levels of competition often depends heavily on the explosive leg power of the athletes involved. Many team sports also require high levels of explosive power, such as Basketball, Volleyball, Netball, Rugby and Football codes for success at elite levels of competition. Explosive power comes from the development of speed strength and pure strength. Power represents the amount of work a muscle or muscle group can produce per unit of time (Shorten, 1991). Until recent years power as it relates to sports performance has been the subject of limited research, but in the last decade or so researchers has realized the importance of training for power in a wide variety of sporting activities (Clutch et al., 1983).

Vertical and horizontal jumping, in its many different forms, requires high levels of explosive muscular power. Brukner and Kahn (1997) note power as the equivalent of explosive strength. According to Brukner and Khan (2001), power is the equivalent of explosive strength. Young and Bilby (1993) used the term "speed-strength" synonymous with power. Paavolaienen et al (1999) suggested that muscle power is the ability of neuromuscular system to produce power during maximal exercise when glycolytic and oxidative energy production is high and muscle contractility may be limited.
1.7.9. Leg Explosive Power

The strength of the muscles in the limbs is moving and supporting the weight of the body repeatedly over a given period of time in terms as dynamics strength, sometimes, it has been called velocity or speed. The important aspect of this factor is the requirement that the muscular force must be repeated as many times as possible. Explosive strength and dynamic strength involve movement of the body or of its limbs.

1.7.10. Cardio Respiratory Endurance

Cardio respiratory endurance refers to the ability to sustain work for prolonged periods. During competitive sports, these systems attempt to supply oxygen to the working muscles. Most of this oxygen is used to produce energy for muscular contraction. Any activity that continuously uses large muscle groups for twenty minutes or longer, taxes these systems. Because of this, a wide variety of training methods are used to improve cardio respiratory endurance.

The kind of endurance associated with cardio-respiratory system is characterized by a physiological fitness, and is related to the phenomenon of ‘wind’. In this instance, exercise is carried on for sufficient duration and intensity, to stress the circulatory and respiratory systems. Such endurance enables the individual to sustain moderate contraction of the skeletal muscles over a comparatively long period of time. The adjustment in the heart, lungs and circulatory systems just mentioned can be made more efficient through training. The best tests to measure this facet of motor performance are long distance running and the treadmill run. The fit individual has a cardio-respiratory system which is capable of meeting the demands of the tissues under conditions of intense exercise.

1.8. OBJECTIVES OF THE PRESENT STUDY

The following are the objectives of the present study.

1. To identify the status of University level sportsmen the motor fitness components speed, agility, muscular strength& endurance, flexibility, arm strength, leg strength, arm explosive power, leg explosive power, cardio respiratory endurance were tested.
2. To study the individualized training effect of Resistance followed by Plyometric Training (RPTG) and Plyometric training followed by Resistance training (PRTG) on speed, agility, muscular strength endurance, flexibility, arm strength, leg strength, arm explosive power, leg explosive power, cardio respiratory endurance components of University sports men

3. To compare the effects of two methods of training namely Resistance followed by Plyometric Training (RPTG), Plyometric followed by Resistance Training (PRTG) and Control group (CG) on the motor fitness components speed, agility, muscular strength endurance, flexibility, arm strength, leg strength, arm explosive power, leg explosive power, cardio respiratory endurance of University sports men.

1.9 STATEMENT OF THE PROBLEM

The main purpose of the study was to find out the effects of varied forms of complex training on speed, agility, muscular strength endurance, flexibility, arm strength, leg strength, arm explosive power, leg explosive power and cardio respiratory endurance of University sports men.

1.10 HYPOTHESES

The hypotheses formulated in the present study are as follows.

1. In studying the individualized effect, it was hypothesized that Resistance followed by Plyometric Training (RPTG) and Plyometric followed by Resistance Training (PRTG) on selected motor fitness components of University sportsmen may have a significant improvement from base line to post treatment after twelve weeks.

2. It was hypothesized that there may be significant mean differences between two methods of training namely Resistance followed by Plyometric Training(RPTG), Plyometric followed by Resistance Training(PRTG) and Control group on selected motor fitness components of University sportsmen.

3. It was hypothesized that Resistance followed by Plyometric Training (RPTG) may be the better training to produce significant improvement on power related components (arm explosive power and leg explosive power) of University sportsmen.
4. It was hypothesized that Plyometric followed by Resistance Training (PRTG) may be the better training to produce significant improvement on strength related components (arm strength and leg strength) of University sportsmen.

5. It was hypothesized that Resistance followed by Plyometric Training (RPTG) and Plyometric followed by Resistance training (PRTG) may have significant development on selected motor fitness components as compared to Control group (CG).

1.11 SIGNIFICANCE OF THE STUDY

The present study is significant in the following aspects.

1. The salient feature of the applications of two training modules namely Resistance followed by Plyometric Training (RPTG) and Plyometric followed by Resistance Training (PRTG) used in the present study is to find out the suitable way to develop the motor fitness components (Speed, Agility, Muscular strength & Endurance, Flexibility, Arm strength, Leg strength, Arm explosive power, Leg explosive power and Cardio respiratory endurance) more effectively.

2. The interventions such as Resistance followed by Plyometric Training (RPTG) and Plyometric followed by Resistance Training (PRTG) used in the present study are a scientifically structured one. Hence, it is believed that sportsmen treated with this training programme can be benefited on time with regard to the development of selected motor fitness components of university sports men.

3. The present study would provide a scientific base and guidance to the physical educationists, coaches, sports scientists, exercise physiologists and fitness leaders to design the complex training programme using the training modules in the present study with the view to develop variables related to motor fitness.

4. One of the basic objectives of the present study is to extract the full potentials from the players with the feasible means and methods. Having the usage of full potentials, low achievers can be easily made as high achievers. It helps them to compete with teams on par with them and succeed.
5. Finding of this research study would give a basic knowledge to the trainers and fitness leaders to envisage and conduct further research in various training methods, training programs, training intensity and training load to enhance the performance.

6. Generally there is a chance of sportsmen getting injured during the course of training itself, since the given training is progressive in nature with rest. But in the case of effect of complex training, the mode of training is alternative form of and high in intensity. The period of slow form of training provides both recovery and maintains the resultant effect. By this, the players can be benefited to continually participate in the training instead of dropping out from the training due to injury.

7. The result of this study would add to the quantum of knowledge in the areas of training methods, fitness and wellness, exercise physiology and exercise science.

8. The periodical evaluation of players on criterion measures helps the players know their level of progress over the period of time. It helps them motivate themselves to actively participate in the training program.

9. Further, the results on periodical evaluation on criterion measures helps the physical trainers and coaches find out the status of players at varied intervals.

1.12 DELIMITATIONS

The delimitations of the study are as follows.

1. Subjects of the present study were delimited to the sportsmen who represented Karunya University in various sport.

2. The total number of subjects was delimited to sixty and each group was comprised of twenty sportsmen.

3. As far as motor fitness components are concerned it was delimited to Speed, Agility, Muscular strength & Endurance, Flexibility, Arm strength, Leg strength, Arm explosive power, Leg explosive power and Cardio respiratory endurance.

4. The period of training program was delimited to twelve weeks.
1.13. LIMITATIONS

The limitations of the present study are as follows:

1. The influence of certain factors like life style daily routine work, diet and other factors on the results of the study were not taken into consideration.

2. No attempt has been made to control the factors like air resistance, intensity of light atmosphere and temperature during training and testing period.

3. The difference in economic and educational background of the subjects were not taken into consideration.

4. The knowledge of the subjects in exercise science and their previous experience in doing physical activities were not taken into consideration.

5. Since the subjects were motivated verbally during testing and training periods no attempt was put to differentiate their level of motivation.

6. The psychological stress and other factors, which affect the metabolic function were not taken into consideration.

7. The heredity of the subjects and its influence on the selected variables were not taken into consideration.

1.14 DEFINITION OF OPERATIONAL TERMS

1.14.1 Speed

Speed is the ability to move quickly across the ground or move limbs rapidly to grab or throw.

1.14.2 Agility

Agility is defined as "the ability of a system to rapidly respond to change by adapting its initial stable configuration".

1.14.3 Muscular strength endurance

Muscular endurance is defined as the ability of a muscle or muscle group to exert force to overcome a resistance many times.
1.14.4 Flexibility

‘Flexibility is the ability to move joints’. Flexibility is defined as the ability to do wide range of movement at joints. It indicates the capacity to bend and extend the body parts without any difficulty beyond the normal position.

1.14.5 Arm Strength

Physical strength is the ability of a person to exert force on physical objects using muscles. Increasing physical strength is the goal of strength training.

1.14.6 Arm explosive power

An explosive is a reactive substance that contains a great amount of potential energy that can produce an explosion if released suddenly, usually accompanied by the production of light, heat, sound and pressure.

1.14.7 Leg explosive power

It is essential that explosive strength play a large role in training, as it is not only a means of developing absolute strength but also a method of raising physical fitness that is directed toward solving a specific sports task.

1.14.8 Cardio respiratory endurance

Cardio respiratory endurance refers to the ability of the body to perform prolonged, large-muscle, dynamic exercise at moderate-to-high levels of intensity. Cardio respiratory endurance is an important part of overall physical fitness.

1.14.9 Complex Training

It is a training comprising of resistance and plyometric exercises